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Regional Challenges in Tourist Wetland Systems: An Integrated Approach to the Ria Formosa Area

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Abstract

Coastal change and coastal erosion have been a long existing source of human distress. Traditionally, this problem has been associated with the agro-food sector and the demand for products, where regional changes in wetland systems and their relations to parasitic infections were a major cause for concern. This was also the case for the fisheries sector, where often local catches would support regional economic activity. Nowadays the paradigm has changed, and coastal distress has reached more global proportions: the problems of coastal change are strongly linked to the loss of fragile ecosystems, eutrophication, and loss of biodiversity. The issue of coastal degradation is further extended to economic activity, where urban growth in coastal areas has led to unprecedented impacts on the carrying capacity of such areas. Given that over 70 per cent of all human activity is in coastal areas, it is clear that many environmental and socio-economic changes occur at a local level and manifest themselves in a spatial context (Turner, et al., 2004). The physical effect on the geographic morphology is evident in the related consequences for land use. A deep understanding of the changes in land use, and simultaneously in coastal erosion, calls for the integrated monitoring of the most relevant effects in fragile regions.

The Ria Formosa wetland system is a unique and very special wetland system in the Algarve, and has been integrated in the NATURA 2000 network. The strong symbiosis between nature, agriculture and fisheries, as well as tourism, in the Algarve has led to spatial-ecological synergy. By using coastal recession analysis techniques by means of remote sensed imagery from 1987, 1989, 2000, 2007, and by combining this information with available data sets on surface erodibility, a cost surface on multi-temporal transitions of land use classes from the CORINE Land Cover data allows us to assess and integrate a decision-making framework, using Geographic Information Systems as a tool to visualize, manipulate, and enhance the regional and local decision-making process in terms of integrated spatial changes. The novelty of this combined approach to land use management is the blend of spatial analysis and remote sensing techniques that share important information on ecosystems at risk. This will be illustrated for the case of the Ria Formosa where: (1) there is an increasing loss of coastal area, leading to eutrophication of the basin and changes in biodiversity; (2) the loss of certain land-use types is accompanied by erosion processes at a regional scale which have negative impacts for the existing dune systems; (3) anthropogenic activity with an increase in urbanization processes is having an adverse effect on forest and agricultural areas. The above methodology and the availability of data which are freely available render such a combined approach interesting for many other regions of the world, where tourism, coastal change and regional balance are of the utmost importance for sustainable development.

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1. Introduction

Coastal zone erosion has become a source of deep policy concern and of strategic and innovative research in the environmental sciences. In the report "Lessons from the European Commission's Demonstration Programme on Integrated Coastal Zone Management" (European Commission, 1999), the difficulty of providing a clear definition and identification of coastal zones is evident. One of the main reasons for this difficulty in formulating an unambiguous definition of coastal zones stems from the complex coastal dynamics in integrating social, economic, and natural forces, but also from the scaling of spatial phenomena. From a socio-economic perspective, wetlands and coastal areas are the prime location for most anthropogenic activity, and the management of these areas is of paramount importance (Costanza et al., 1989), even more so at the regional level (Gilbert et al., 2004). The growing concern about coastal zone management is reflected in policy initiatives, given the increasing pressures (Reis and Lowe, 2012) on sustainability and resilience throughout the coastal regions in Europe, with particular concern for southern Europe (EEA, 2006). In the course of its history, Portugal has had an important synergetic relation with its coast (Cardoso et al., 2011). It has one of the largest coastal areas in relation to country size in Europe, and national laws have led to planning initiatives in the Portuguese coastal areas since 1864 owing to the presence of commercial routes, but in Portugal the tradition of expanding human activity within a socio-economic context dates back to the 15th century, when discoveries where cartography was already of key importance (Kimble, 1933). The POOC (Planos de Ordenamento da Orla Costeira *trans.*: Territorial Plans of Coastal Zone Organization) decree n. 309/93 of 2nd September 1993 and 218/94 of 20th August 1994 consider the coastal zones to be a buffer area of 500 metres along the shoreline as well as having an additional bathymetric line up to 30 metres from the shoreline. The authorities involved in coastal response have expressed increasing concern for coastal erosion and climate change in Portugal (Andrade et al., 2007). Regions such as the Algarve, the southernmost region of Portugal, are particularly vulnerable, given the existence of fragile ecosystems and the location of the major urban infrastructures (Vaz et al., 2011a). Coastal erosion is leading to the loss of these fragile ecosystems and is an increasing threat to economic activities as well as to natural and historical landscapes (Vaz et al. 2011b). A decline in the quality and quantity of water has led to the destruction of habitats, and loss of biodiversity. The reduction of hydrological resources disturbs the equilibrium of ecosystems (Hellström et al., 2000). The deterioration of these ecological sinks is also undermining the quality of the landscape, which has an adverse effect on landscape - dependent activities such as tourism. As a result, there are negative externalities, such as unemployment, social instability, loss of landscape value, and the consequence is a disruption of both the economic and the ecological cycle. In the Algarve, a region which is strongly dependent on tourism, this is likely to have dramatic consequences for its economic activity, which has been one of the leading economic drivers both at the national and regional dimension. The aim of this paper is to assess coastal erosion combined with a markov probabilities of possible future change for the area of the Ria Formosa. The application of coastal erosion models at local level related to the changes in land-use patterns is a novel research direction

embroidered by the availability of spatial data possible to integrate and manipulate in a GIS. Starting with a spatial analysis and integration of the study area, we propose to derive the coastal erosion patterns and change patterns compared to available land-use, integrating this in a prospective decision making context for regional planning, where both erosion, coastal erosion and land-use change are of utmost importance in a context of regional environmental change where increased availability of data is one of the key assets for multi-dimension spatial analysis based on regional and local geographic information.

2. Study Area

The Algarve region is the most southern region of Portugal, and its district capital Faro is located at 37°0′52″N 7°56′7″W. With an average elevation of only 11m, the Algarve has had a long tradition of using its coastal area as the main provider for the regional economy. The Algarve has had one of the most important fishering industries in Portugal since the 19th century. Since the 1960s the Algarve has been transformed into one of the most important tourist regions of Portugal, and its coastal area is characterizes by offshore sandbars which form several islands and unique wetland ecosystems such as the Ria Formosa. These special characteristics mean that the Algarve is very dependent to its coastal areas which belong to the agricultural wetland system (in particular for salt production). The Algarve takes its name from the Moorish name "*Al-gharb*" (*transl.* The Beacon), showing the geographical importance of the region for the southern and Eastern civilizations during the Middle Ages. According to Strabo, the geographer, during the period of the Roman Empire, the Algarve served as one of the most important trading routes. The production of *Garum,* one of the most common spices throughout the Roman Empire, was common in the region of the Algarve and exported in stone jars throughout the Roman Empire through land and sea. This salty fish sauce was a mixture of fermented fish with spices and quite common in many of Roman dishes. In the late 19th century, the Algarve became one of the most important fisheries throughout Europe. The ancient production of *Garum* facilitated the tradition of canned sardines and the fishing industry throughout the Algarve, which became a major driver of economic prosperity until the 19th century. Although this historical agro-food sector has greatly diminished over the last 60 years, the Algarve has become one of the most appealing Tourism destinations of Europe. The aesthetic value of the unique littoral ecological landscape and the mild climate facilitated the development of a mass tourism industry, which nowadays is the main economic driver of the Algarve. All this explains the close relation that the Algarve has with its coastal regions which at present, and in the future, are of the utmost importance for its continued economic prosperity. To maintain biodiversity and to contribute to sustainable development, most of the ecological regions are part of the NATURA 2000 initiative, which has addressed seriously threatened habitats throughout Europe since 1992. A total of 38.6 per cent (193000.5 ha) of the inland territory is part of this network, and is characterized by unique ecological richness. This corresponds to 16 sites with particular ecological, biological, and geographical characteristics, which together form unique habitats in the region. The following sites are currently part of the NATURA network

(together with their special conservation numbers): *Costa Sudoeste* (PTCON0012), *Leixão da Gaivota* (PTZPE0016), *Arade / Odelouca* (PTCON0052), *Ria de Alvor* (PTCON0058), *Ria Formosa – Castro Marim* (PTCON0013), *Ribeira de Quarteira* (PTCON00038), *Ria Formosa* (PTZPE0017), *Sapais de Castro Marim* (PTZPE0018), *Monchique* (PTCON00037), *Cerro da Cabeça* (PTCON0050), *Barrocal* (PTCON0049), *Caldeirão* (PTCON0057), *Guadiana* (PTCON0036), *Vale do Guadiana* (PTZPE0047). It is only natural as a result of socio-economic growth, that, the main settlements in the Algarve are located along the littoral. Excessive pressure from urban sprawl related to continued eutrophication (Zaldivar et al., 2008) is leading to permanent loss of the 16 sites which form part of the NATURA 2000 Network in the Algarve (Figure 1) and often also linked to economic processes (. Of these 16 sites, six are particularly vulnerable to coastal erosion, as they are located within wetland ecosystems. These regions are also prone to additional pressure caused by urban sprawl and population growth.

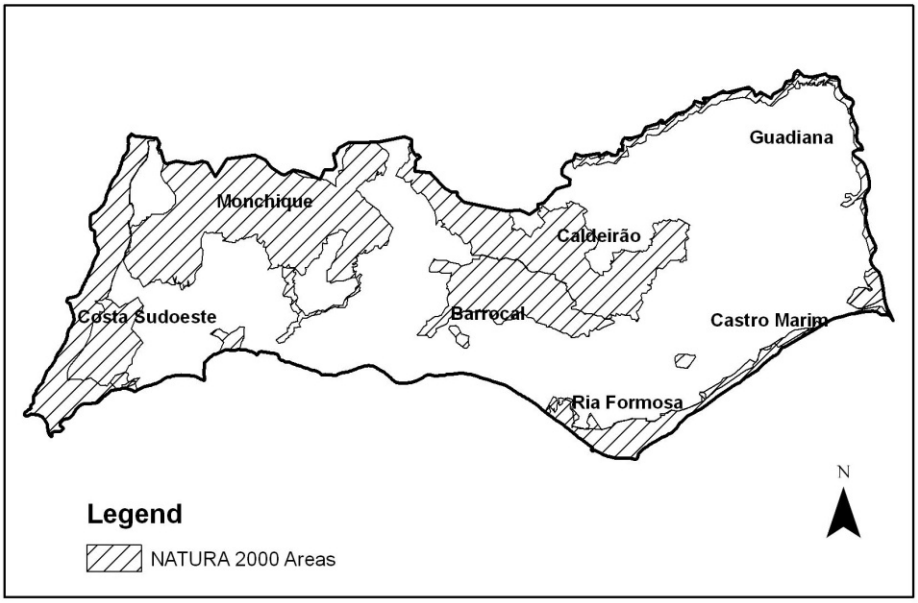


Figure 1 – The Algarve and its natural geomorphological divisions

The combination of climate change, land use change, and coastal erosion in the Algarve creates an important problem which puts at risk the continued economic development at the regional level by its impacts on the tourism industry, as well as leading to the destruction of ecosystems, archaeological landscapes, beach areas and in future, urban areas. This problem is, moreover, accompanied by adversities that are affecting the natural drainage system of the region and which spread out to the coast, given the close proximity the mountain range to the north. The natural lagoons formed along the coastline are a place for many edaphic species and provide strong hope for ecotourism activity in the region. However, increasing urban pressure is leading to the destruction of these natural environments, while natural factors such as cliff retreat are leading to further strain (Dias and Neal, 1992). This is jeopardizing some of the protected ecosystems that are part of the NATURA network. As such, a constant monitoring of

coastal erosion in the Algarve is essential: at this spatial level, in order to better understand the dynamics of spatio-temporal change and create stronger and more effective legislation relating to the decision-making process for sustainable regional development. While most of the coastal erosion studies in the Algarve rely on aerial remote sensing, Catalão and others (2002) have made a systemic analysis based on such imagery from 1938 up until 1995, showing that morphological changes in the stretch of the Algarve coast between Olhos de Água and the Quarteira river have been significant. A total of 10.83 m and 9.7 m of the shoreline were assessed in this study for two different zones in the time frame. The continuous strain has now become spatially evident, and suggests an increase in climate change.

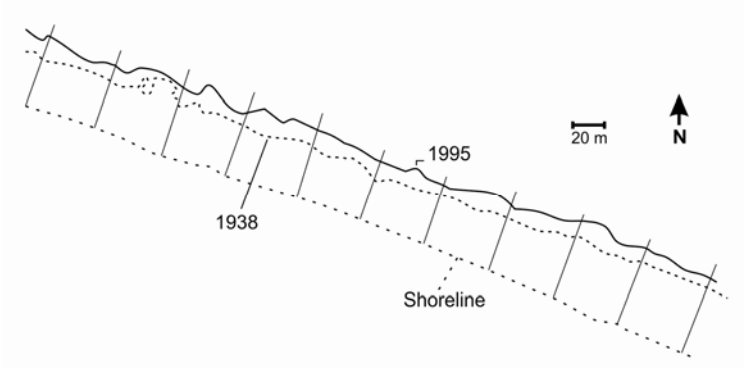


Figure 2 – Top cliff line for the years 1938 and 1995 (adapted from Catalão, et al., 2002)

Adding to this phenomenon, the impacts on the urban surface have also been felt strongly over recent years, and many houses in small cities such as Fuzeta, part of a natural dune system of Faro island, have been irrecoverably lost. The continuous strain on the vulnerable stretches in the Algarve call for an integrated approach, where not only the morphological consequences are assessed at the coastal erosion level, but also the differences to the land use types and their sustainability within the anthropogenic dimension are considered. The integration of satellite based remote sensed imagery has an important role in assessing the issue at a more regional level, especially when combined with land-use variations of existing sub-classes of land cover and urban dynamics. The multi-temporal availability of these data sources, for both anthropogenic land use and the geophysical characteristics of satellite imagery leading to a more complex spatial interpretation of the different dynamics.

3. Database

3.1 Erosion Data

The PESERA (Pan-European Soil Erosion Risk Assessment) model, started on 1 April 2000 and ended on 30 September 2003 as an attempt to examine the spatial distribution of erosion risk in Europe (Kirkby et al., 2004). As a factorial scoring method (Morgan, 1984) it is an evolution of the CORINE soil erosion risk assessment developed a decade earlier. These methods are largely based on scores, and thus a problem with the way the scores are defined may remain. In contrast, model-based approaches measure the combination of hill and slope data and data on rainfall intensity, infiltration and

sediment transport patterns, which require the provision of information based on meteorological data, soil maps, multi-temporal satellite imagery and digital elevation. One of the advantages of quantitative model assessments for soil erosion is the aggregation of data on a local scale despite the fact that geomorphological factors can vary greatly over larger scales. The accuracy of the provided models also is based on regression estimates, but collected samples can bias interpretation and results of concerning erodibility. Both Expert-based and model-based approaches share common problems related to the difficulty of validating produced estimates, leading to a component of uncertainty, and this questions the overall reliability of the models produced. The ease of application of the PESERA model and the 1x1 km grid for Europe of possible erosion, are, however, important assets for deriving a generic methodology for a multi-purpose application in the complex spatial system dynamics framework. One of the main integrations of the PERSERA Model is the relationship of the runoff threshold with existing vegetation patterns and soil types. The model produces a similar result to the RUSLE model which also takes advantage of Landsat satellite imagery (for the calculation of the C-factor). The recent addition of the K-factor map with erosion potential for entire Europe (Panagos, et al., 2012) are a crucial contribution towards the production of an assessment of land use change transitions within the coastal and wetland erosive stretches that combine an share similar results to the RUSLE and the previously existing PESERA project, but offer at global level a higher spatial resolution for better local assessment.

3.2 Satellite Imagery

The Global Land Cover Facility (GLCF) was established in 1998 as a NASA Earth Science Enterprise Partner, and it is a joint project between the University of Maryland's Institute for Advanced Computer Studies (UMIACS) and the Department of Geography. The main aim of the GLCF (Figure 3) is to provide, free of charge, satellite imagery, derived products and applications to science communities in order to understand changes occurring on the Earth's surface, with a focus on the land cover. Large volumes of different types of data have already been assembled and integrated into a database such as (i) information derived from satellite imagery (Aster, Ikonos, Quickbird, Orbview, Landsat, Modis, SRTM), (ii) products derived from satellite imagery such as: Forest Change Products, Coastal Marsh Health Index, Flood Maps, Vegetative Cover Conversion, Vegetation Continuous Fields, Vegetation Index, Water Mask, Radiative Fluxes, GLSDEM): and, (iii) Vector products. The integration of the WebGIS component enables querying and selecting data based on date properties, location or a combination of parameters, and can then be downloaded via a web application called Earth Science Data Interface (ESDI).

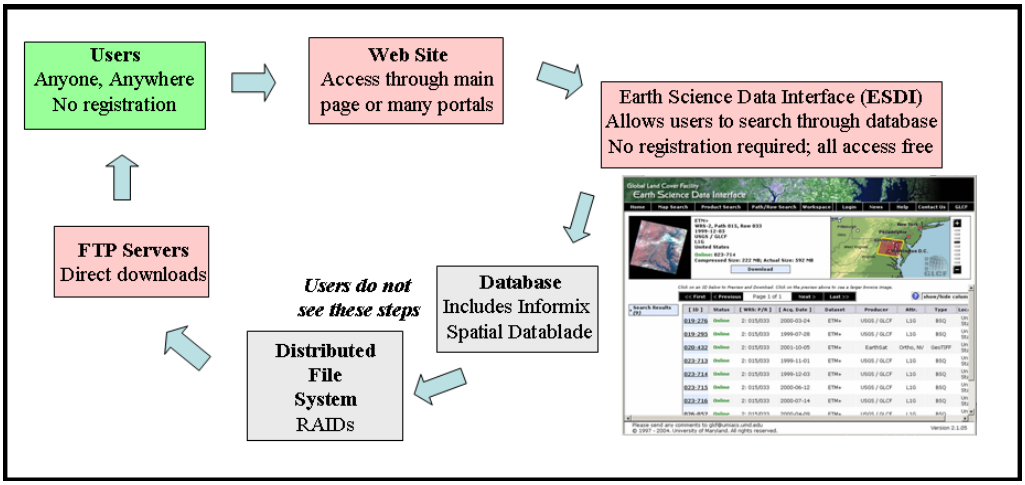


Figure 3 - The structure of the GLCF

To assess the transitional coastal change effects on the Ria Formosa, data has been selected and downloaded from the Global Land Cover Facility sources. Available data for the selected area have already been orthorectifed by Landsat 5 TM and Landsat 7 ETM+ imagery (Table 1) .

Acqusition date	**1987-05-21**	**1989-03-23**	**2000-06-01**	**2007-03-09**
Satellite	Landsat5	Landsat5	Landsat7	Landsat5
Sensor	TM	TM	ETM+	TM
Resolution [m]	30	30	28.5	30
Map Projection	UTM, WGS 84, ZONE 29			
Ellipsoid, Datum	WGS 84			
Product	Orthorecified			

Table 1. Satellite imagery information for Ria Formosa

3.3 Land Use Information

Developed in the 1980s, the CORINE Land Cover (CLC) project was used to provide land-use information. The spatial information of this database is strongly linked to the availability of multi-temporality. This multi-temporal scope is only possible due to the different dates of production of land-use maps for CLC. As such, for an initial assessment, we used CORINE Land Cover 1990 (CLC90) and for land use change purposes, compared it with the land-use/cover types of CORINE Land Cover 2000 (CLC2000). The comparison of CLC90 and CLC2000 originated an assessment based on the smallest unit mapped at 25 ha of land use change. Both these data source were combined in order to benefit from the main advantage of GIS as a tool to analyse, maintain, and manipulate spatial data, leading to an accurate interpretation of spatial land use change and transitions for the Ria Formosa (Figure 4).

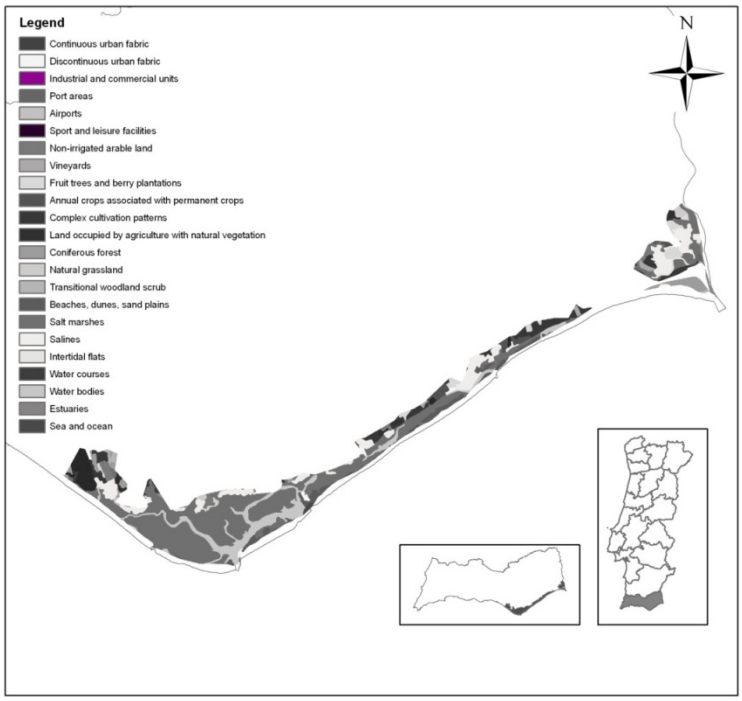


Figure 4 – Location of the Ria Formosa reserve and land use in 1990

At the 1:100,000 scale (EEA, 2008), there are three temporal of analysis CLC90, CLC2000, and CLC06.The primary classes we may assess artificial surfaces, agricultural areas, forests and semi-natural areas, wetlands and water bodies. Subsequent disaggregation of these classes leads to 44 available classes, which adopt the common CORINE nomenclature (Caetano et al., 2008). Currently in its third edition, the CLC is updated at 10 year intervals. The reason for such a delayed update is strongly linked to the resources and the complex task of gathering and filtering available information, as well as integrating the different European key-players in the projects development. A ten-year interval is certainly a large time frame to capture certain activities related to micro-spatial simulation, as ongoing change might not be picked up with such a large gap of time. However, for analysis that embraces coastal recession and climate change phenomena and especially at a regional level, it serves as an excellent tool for quantitative land use analysis, decision making processes, and the geovisualization of land change properties. Regional interpretations of urban sprawl in Europe, as well as assessments of land-cover loss and structural changes in agricultural land-use classes, have been widely assessed. For the three existing CORINE Land Cover Levels the level of accuracy was tested for Level 1 at 97.59 per cent, Level 2 90,12 per cent and Level 3 at 82.84 per cent by means of comparison with data from the MURBANDY project for the Algarve region holding a 1ha spatial resolution . The following table shows the overall error matrix for CLC 2000 produced for the subclasses of wetlands and water bodies.

CLC 2000	CLC – REF										
	411	**421**	**422**	**423**	**511**	**512**	**521**	**522**	**523**	**Total**	**Accuracy %**
411	0	0	0	0	0	0	0	0	0	0	100%
421	0	1064	0	0	0	0	0	0	0	1064	100%
422	0	0	519	0	0	0	0	0	0	522	99%
423	0	0	0	116		0	0	0	0	116	100%
511	0	0	0	0	99	0	0	0	0	99	100%
512	0	0	0	0	0	237	0	0	0	237	100%
521	0	0	0	0	0	0	51	0	0	51	100%
522	0	0	54	0	0	0	0	1148	0	1202	96%
523	0	0	0	0	0	0	0	0	21	21	100%

Table 2 – Error Matrix of CLC 2000 Wetlands and Water bodies classes

4. Methodology

4.1 Delineating coastal recession through satellite imagery

Several methods have been developed to detect coastline recession using satellite imagery. The simplest one is based only on one of the infrared bands. The reflectance in the infrared band, where water is nearly equal to zero, and the reflectance of most of the land coverage which is greater than water (Chand and Acharya, 2010) provides important results on the coastal recession patterns. For such purposes the histogram tresholding (HT) method is used. Owing the very low reflectance of water and high reflectance of vegetation, the histogram displays two peaks, exhibiting a strong contrast between land and water (Figure 5). The transition zone is the effect of mixed pixels and moisture regimes between land and water which is why it is quite difficult to find a proper threshold value (Kamthonkiat et al., 2010). To reduce the influence of the threshold value choice and to improve extraction of the coastline, a second condition is introduced: the ratio of the satellite band 2 and satellite band 5 is greater than 1 for water and less than 1 for land in large areas of the coastal zone (Alesheikh et al., 2007).

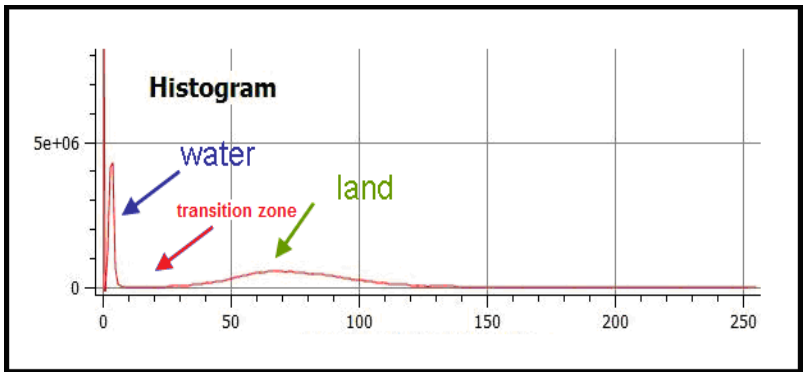


Figure 5 - Histogram of the band 5, Landsat TM-1989

This methodology (Figure 6) was applied for the Ria Formosa given the spatial and distilled remote-sensed characteristics which guarantee optimal circumstances on a multi-temporal basis for such assessment. Shorelines from the years 1987, 1989, 2000, and 2007 have been detected and extracted using two versions of open source software. The resulting output was performed by ILWIS (version 3.0) resulting in the vector form of the coastline. The results were then exported, as a shape file to Quantum GIS (1.7.2 version) for smoothing and improving the edge/boundary between water and land based on a colour composite of bands 5, 4, and 3, showing a decent water-land interface.

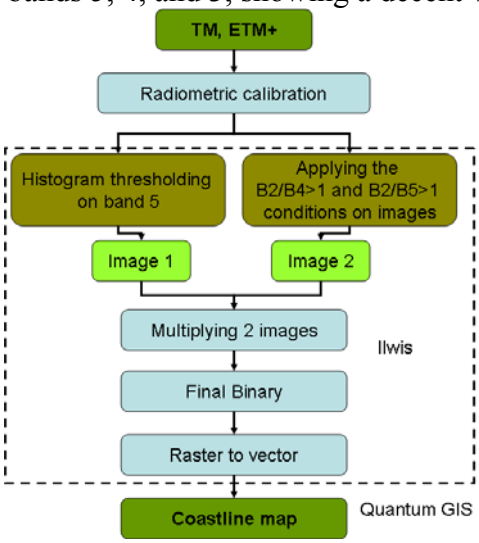


Figure 6 - Methodology of extracting coastlines from images (Alesheikh et al., 2007).

This allowed us to identify several important features through geovisualization for the Ria Formosa assessed within an overlay of a band composition in RGB of Band 5,4,3 (Figure 7), and then a quantitative interpretation allowed us to state that: (i) there is a strong propensity for coastal recession for the entire Ria Formosa stretch, this pattern is also present in the entire coastal region of the Algarve; (ii) the most dense recession pattern emerges eastward towards the river Guadiana, extending into Spain, (iii) the greatest changes occurred between 198 and -2000, taking into account the inter-zonal and tidal aspects of the studied period of 1987 to 2007.

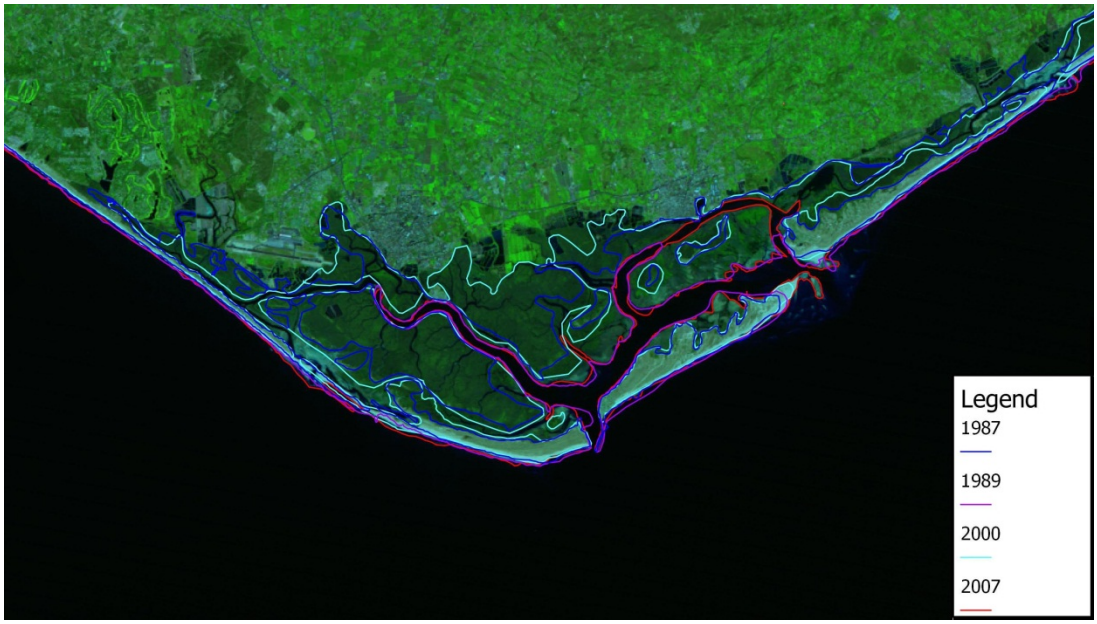


Figure 7 – Evolution of the coastline of the Ria Formosa area 1987-2007

High importance was given to the orthorectification phase, where planimetric accuracy is essential for comparison on a multi-temporal basis. Extracted shoreline features hence result from naturally formed boundaries between contrasting water and land features. The interaction of water and land, given the shallow water properties had to be considered effectively in the several imported dates, so as to give attention to the multiple stages of inter-zonal sea level changes.

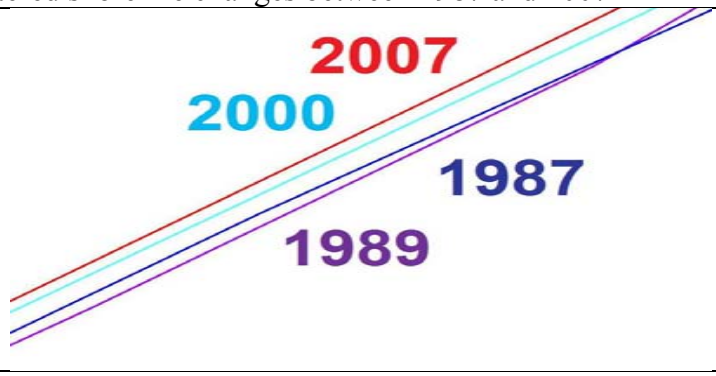
Shoreline position in 1987	Shoreline position in 1989
	
Shoreline position in 2000	**Shoreline position in 2007**
	
	Registered shoreline changes between 1987 and 2007
	

Figure 8 – Multi-temporal shoreline positions and registered shoreline changes

4.2 Incorporation of grid based K-Factor data for the European Union

The downloaded K-Factor data based on LUCAS point data extrapolated by Panagos and others (2012), served as base information to integrate erosion information within the GIS. The dataset for Europe with a 10km pixel size, needed some additional inference for completion of the total information for Ria Formosa. The creation of a vector grid for spatial extrapolation of pattern characteristics at the regional level (Vaz et al., 2011) allowed covering the area of the Ria Formosa with missing values existent due to the 10km pixel size (Figure 9). In this way, the total grid was extended by maximum likelihood estimation for the area encompassing the total ground surface of the Ria Formosa.

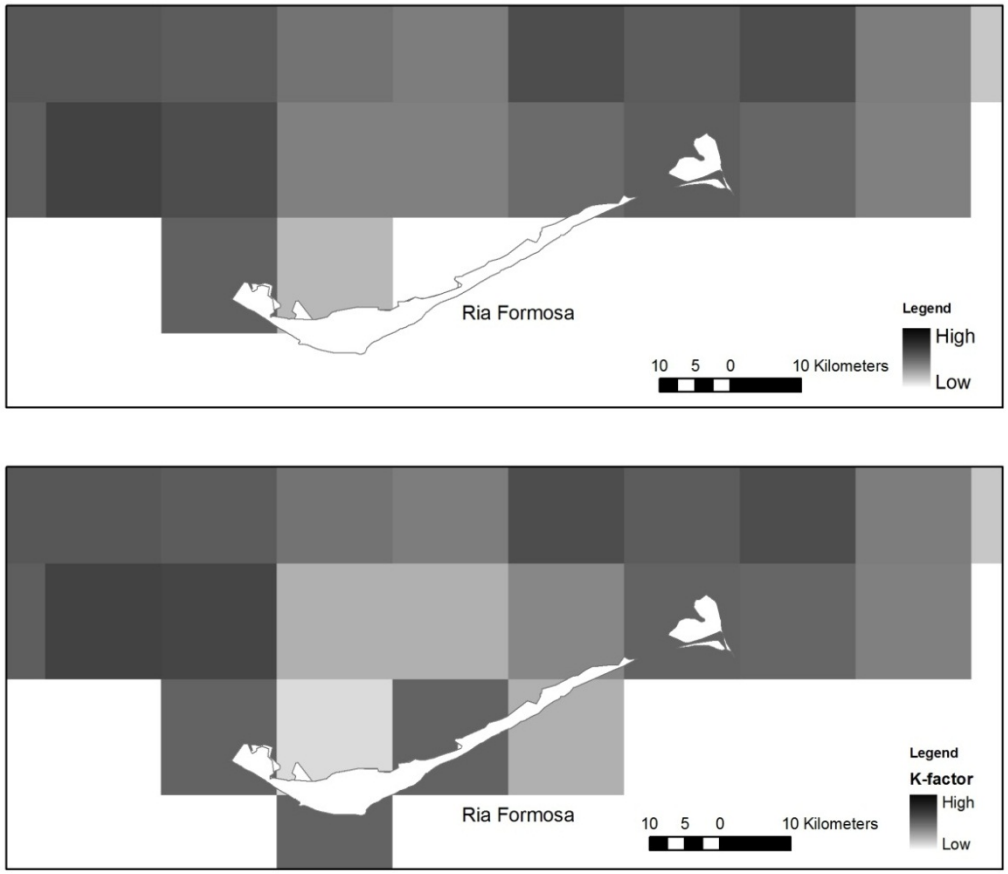


Figure 9 – Extrapolated K-Factor weight for the Ria Formosa

5. Discussion

The combination of the integrated patterns formed in land use transitions with regional coastal dynamics are largely enhanced due to the support of GIS for regional decision making (Nijkamp and Scholten, 1993). A large set of possibilities exists for geovisualization purposes, but also multi-temporal comparative analysis within the forecasting of coastal erosion processes (Feagin et al., 2005). By means of a Markov transition matrix frequencies of changes in each cell were assessed between the period of CLC90 and CLC06. The Markov transition matrix used, which was developed in Idrisi (Eastman, 2006) randomized the possibilities of land change for any cell, with addition to the cost surface calculated through the ongoing coastal recession and erosion pressures mentioned in the previous section and provides an interesting method for

analysing existing land use changes over time and space (Munsi et al., 2010). The combination of this information enabled for an exact extraction of the most endangered land use types within the Ria Formosa including a spatio-temporal interpretation of land use dynamics prone to both types of erosion. Regarding the study area, most significant changes were present between CORINE Land Cover 1990 and CORINE Land Cover 2000. The significant changes are related to a strong decrease of salt marshes and among complex cultivation patterns. While in CLC 90 salt marshes corresponded to 45.31 per cent of the total Ria Formosa area, only 39.23 per cent were found in the subsequent land covers. A significant and steady increase was registered in the CORINE Land Cover nomenclature defined as artificial land showing the direct impact of human behaviour on the Ria Formosa ecosystem. Based on an initial 5.20 per cent of urban patterns a growth was registered of up to 6.74 per cent for CLC 2000, and of 7.16 per cent for CLC06. These changes (Figure 10) are mainly related to the increase of discontinuous urban fabric and the creation of sport and leisure facilities. Within the sport and leisure facilities, the ecological landscape of the Ria Formosa has been of increasing interest for private stakeholders for the creation of Golf courses. While the complex dynamics of spatial land-use change in the Ria Formosa is evident, the complex patterns seem to be strongly linked to human activity and changes in the geomorphology of the water and wetland systems.

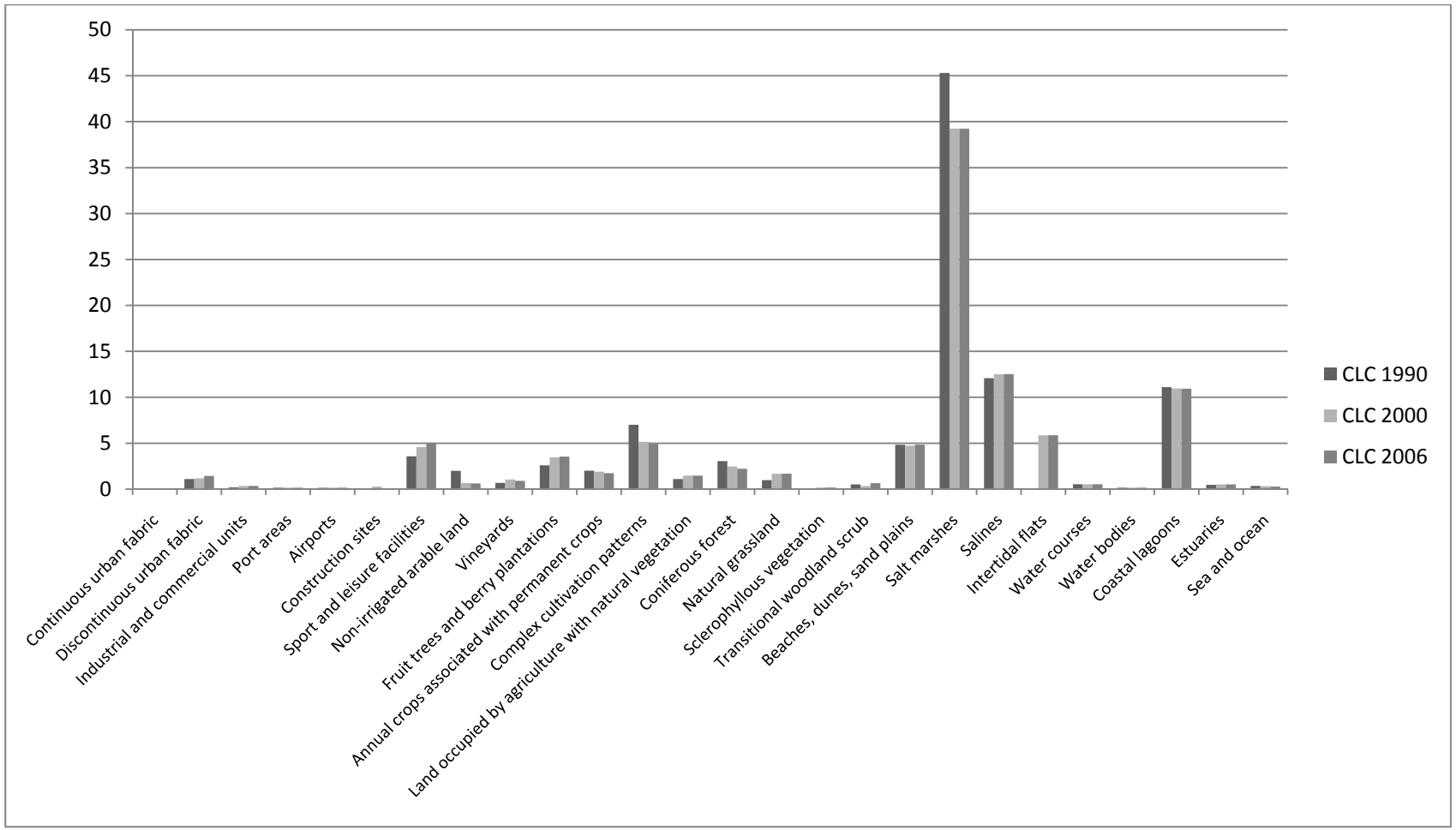


Figure 10 – Changes in CLC 1990, CLC 2000 and CLC 2006 in the Ria Formosa area, by types of land use

6. Conclusions

The existing pressure on the coastal fringe due to coastal recession and the erosion potential of the Algarve as a whole, but in particular along the Eastern part of the region and affecting locally the Ria Formosa area, suggests a continued loss of salt marshes and increasing salinity o the natural forest cover types. Within the context of climate change, and adding the IPCC perception that coastal recession is in large part the result of human impact, it is possible to observe a continued decrease in natural land cover in the area, predominantly located within the regions of high erosion measured. The slight changes in urban fabric, allied to the increase in leisure facilities, suggest increasing concern about the already vulnerable stretch of the Ria Formosa. On the one hand, the erosion potential with loss of anthropogenic activity is maximized, and, on the other, the fragility of the recessive coastal fringe is leading to two causes of eutrophication for the region. The integration of changes in dunes and sand areas, also located in the area prone to higher coastal recession, suggests that in the next decades a higher probability exists of irreversible changes in the nature of the vegetation and the balance of this lagoon system. The use of GIS and advanced spatial analysis tools, combined with remote sensing and land use information, have enabled a crucial analysis of one of the most vital natural reserves of the Algarve. For decision making and policy planning, the lesson learned is that of the importance of using spatial information for monitoring fragile ecosystems and stretches, but also of using spatial information and remote sensing techniques to measure using existing European data the dimension of change dynamics and impacts on our environment for better regional decision making in fragile coastal stretches.

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